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⑭ ハイドレートの多段分解槽

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⑱ 出 願 昭57(1982) 8月9日

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明 細 書

発明の名称 ハイドレートの多段分解槽

特許請求の範囲

1. 冷凍式海水淡水化装置に設けたハイドレート  
の多段分解槽において、段間オリフィス板のオリ  
フィス下流側にデフレクターを設けたことを特徴  
とするハイドレートの多段分解槽。

2. 段間オリフィス板に対するデフレクターの角  
度を70°～80度、段間オリフィスの径に対する  
デフレクターの長さの比を2.0～2.5とし、かつ  
段間オリフィスの径に対するデフレクターの幅の  
比を5～10とした特許請求の範囲第1項記載の  
ハイドレートの多段分解槽。

発明の詳細な説明

本発明はハイドレートの多段分解槽に関し、詳  
しくは、LNG等の液化ガスを気化させる際に発  
生する冷熱を利用した冷凍式海水淡水化装置に設  
けた効率的なハイドレートの多段分解槽に関する。

ハイドレートは、液化ガスと海水を高圧力下で  
直接接させることにより生成するもので、メタ

ン、エタン及びプロパン等の炭化水素分子のまわ  
りに水分子が結合された包囲接合物の一種である。  
例えば、30 kg/cm<sup>2</sup>の高圧力下で液化ガスと海  
水を直接接させると、海水温度が約8℃でハイド  
レートが生成する。したがって、液化ガスの気  
化に伴う冷熱がこのハイドレートの生成に費され、  
海水中に氷晶が生成する温度の約-2℃に下らず、  
ハイドレートのみが生成する。このハイドレート  
は、外観的には氷晶とほとんど同じであるが、そ  
の粒径は、低圧力下で液化ガスと海水が直接接  
した際に生成する氷晶粒径に比べて1/3～1/4  
の粒子大きさである。

冷凍法による海水淡水化においては、晶析技術  
はもちろんのこと、晶析槽で生成した氷晶あるい  
はハイドレートと濃縮海水(以下ブラインと略称  
する)の分離も重要な技術の1つである。ところ  
で、氷晶あるいはハイドレートとブラインの分離  
性能は、それらの粒子の大きさに左右され、粒子  
径が大きくなると分離性能が向上する。

この分離性能に関連し、添付図面の第1図はブ

(1)

(2)

70°~80°、 $\ell$ 及び $b$ の関係 $\ell/d=20\sim25$ 、 $b/d=5\sim10$ とすることが適当であり、それにより液相部のハイドレート及び氷晶を均一に分散できることが実験により確認された。

次に、本発明を添付図面により具体的に説明する。第3図は、本発明のハイドレート多段分解槽を用いた冷凍式海水炭水化装置の一具体例を示した系統図、第4図は第3図におけるハイドレート多段分解槽の拡大図であり、1は晶析槽、2は液化ガス気化器、3は液化ガス管路、4はハイドレート、5は気化ガス管路、6は調圧弁、7は海水管路、8は海水の液面、9はハイドレートとブラインの管路、10はハイドレートの多段分解槽、11は氷晶とブラインの管路、12はポンプ、13は分離槽、14は分解ガス管路、15は分解ガス調圧弁、16は氷晶、17はブライン、18は分離部、19はブライン管路、20はオリフィス、21は段間オリフィス板、22は液相部、23は気相部、24はデフレクター、 $d$ はオリフィス径、 $\theta$ はデフレクターの角度、 $\ell$ はデフレクターの長さを示す。

ターの長さを示す。

第3図に示すように、晶析槽1では、液化ガス管路3から圧送されてくる液化ガスが液化ガス気化器2により海水管路7から送られる海水と直接接触して、晶析槽1内にハイドレート4を生成させ、気化した液化ガスは気化ガス管路5、調圧弁6を通じて外部に流出する。晶析槽1内で生成したハイドレートとブラインは、スラリーとなつてハイドレートとブラインの管路9を通り、ハイドレートの多段分解槽10に入る。該分解槽10内でハイドレートはハイドレートから氷晶に転換し、氷晶とブラインの管路11、ポンプ12を経て分離槽13に入る。一方、該分解槽10でハイドレートの分解に伴つて発生した分解ガスは分解ガス管路14、分解ガス調圧弁15を介して外部に流出し、主として燃料として使用される。分離槽13では、氷晶16とブライン17は分離槽13に設けた分離部18にてよつて分離され、ブラインはブライン管路19を介して排出される。

第4図に示されているように、該分解槽10に

は、各段において圧力差を持たせるため、オリフィス20を設けた段間オリフィス板21を備え、これにより区分された各分解室は、ハイドレートの分解ガスよりなる気相部23と、ハイドレートあるいは氷晶とブラインの混合スラリーよりなる液相部22となる。前記したように、分解操作を円滑にし、液相部22に流動性を与えて氷晶及びハイドレートを液相部22全域に均一に分散させるため、オリフィス20の下流側にはデフレクター24を設け、前記した条件のデフレクターの位置、角度、寸法を用いることにより、良好な分解効果を発揮することができる。

以上説明したように、本発明によれば、段間オリフィス下流側に適切な位置、寸法、角度を有するデフレクターを設けることにより、ハイドレートの分解を効果的に行いうる冷凍式海水炭水化用の多段分解槽を提供することができる。

図面の簡単な説明

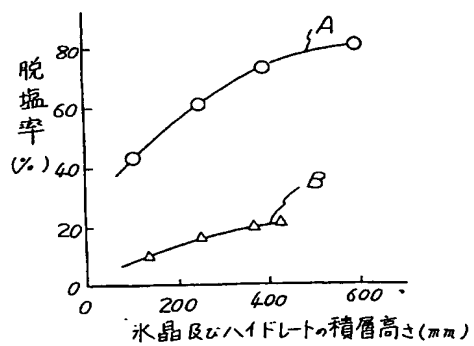
第1図はブライン中からの氷晶及びハイドレートの分離性能を示したグラフ、第2図はハイドレ

ートの減圧分解により生成する氷晶粒径の経時変化を示したグラフ、第3図は本発明のハイドレート多段分解槽を用いた冷凍式海水炭水化装置の一具体例を示した系統図、第4図は第3図におけるハイドレート多段分解槽の拡大図である。

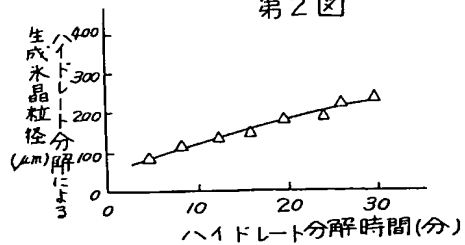
1…晶析槽、2…液化ガス気化器、3…液化ガス管路、4…ハイドレート、5…気化ガス管路、6…調圧弁、7…海水管路、8…海水の液面、9…ハイドレートとブラインの管路、10…ハイドレートの多段分解槽、11…氷晶とブラインの管路、12…ポンプ、13…分離槽、14…分解ガス管路、15…分解ガス調圧弁、16…氷晶、17…ブライン、18…分離部、19…ブライン管路、20…オリフィス、21…段間オリフィス板、22…液相部、23…気相部、24…デフレクター、 $d$ …オリフィス径、 $\theta$ …デフレクターの角度、 $\ell$ …デフレクターの長さ。

代理人 井理士 高橋明

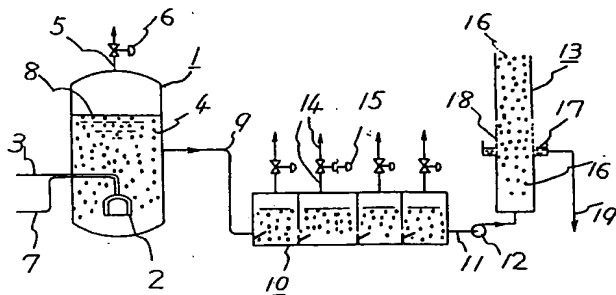
第1図



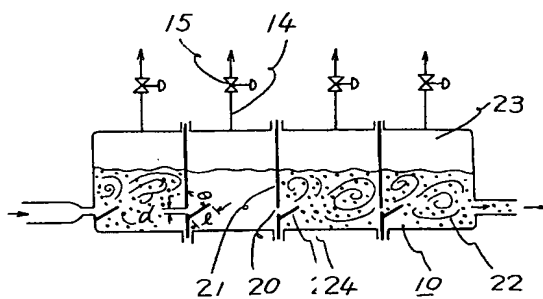
第2図



第33図



第44図



[Page 407, upper half of the page]

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(54) Multi-stage hydrate decomposition tank

(21) Patent Application No.: Sho 57-137215

(22) Date of Patent Application: August 9, Showa 57 (1982)

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[Page 407, lower half of the page]

[Page 407, column (1)]

### Specification

Title of the Invention: Multi-stage hydrate decomposition tank

### Claims:

1. In a multi-stage hydrate decomposition tank provided in a frozen type seawater desalination apparatus, a multi-stage hydrate decomposition tank characterized by a deflector being provided on the down stream side of the orifice on the orifice plate between stages.
2. A multi-stage hydrate decomposition tank as set forth in claim 1, with the angle of the

deflector with respect to the orifice plate between stages being set to 70-80 degrees, the ratio of the length of the deflector with respect to the diameter of the orifice plate between stages being 20-25, and the ratio of the width of the deflector with respect to the diameter of the orifice plate between stages being 5-10.

#### Detailed Description of the Invention:

The present invention relates to a multi-stage hydrate decomposition tank, specifically, to an efficient multi-stage hydrate decomposition tank provided in a frozen type seawater desalination apparatus utilizing cold heat generated when a liquified gas such as LNG is gasified.

Hydrate is formed by a liquified gas and seawater are brought into direct contact under an elevated pressure,

[Page 407, column (2)]

and a type of clathrate compound wherein water molecules are bonded around a hydrocarbon molecule such as methane, ethane, and propane. For example, when a liquified gas and seawater are brought into direct contact under an elevated pressure of  $30 \text{ kg/cm}^2$ , a hydrate is formed at the seawater temperature of about 8EC. Therefore, the cold heat in conjunction with the evaporation of liquified gas is consumed for the formation of hydrate and the temperature does not drop to about 12EC, the temperature at which ice crystals are formed in seawater, and only the hydrate is formed. While this hydrate is nearly the same in appearance as ice crystals, the particle diameter thereof is 1/3-1/4 in particle size as compared to the particle diameter of the ice crystal formed when a liquified gas and seawater are brought into direct contact under a low pressure.

In the seawater desalination method by frozen method, naturally crystallization technology but the dissociation of ice crystals or hydrate formed in the crystallization tank and concentrated seawater (hereinafter referred to in short as brine) is also one of the important technologies. Now, the dissociation performance of ice crystals or hydrate and brine is subject to the sizes of the particles thereof, and the larger the particle diameter is, the more enhanced the dissociation performance is.

[Page 408, upper left-hand column]

As related to this dissociation performance, Fig. 1, which is an attached drawing, is a graph illustrating the dissociation performance of ice crystals and hydrate from within the brine, the horizontal axis showing the height of laminated layer (mm) of the ice crystals and hydrate and the vertical axis desalination rate (%), and, curve A being for ice crystals and curve B for hydrate. This experiment looked into the dissociation performance of the ice crystals formed by a liquified gas and seawater being brought into direct contact under a lower pressure under which hydrate does not form and the hydrate formed by a liquified gas and seawater being brought into direct contact under an elevated pressure of about  $30 \text{ kg/cm}^2$ . As apparent from Fig. 1, the ice crystals (curve A) show high desalination rates as compared to hydrate (curve B).

And, the hydrate has a characteristic such that it decomposes by the pressure being reduced from the pressure at the time of crystallization to the ambient pressure, and about 93 kcal per 1 kg of hydrate is required for the decomposition heat then. Therefore, by the hydrate being decomposed in a container under the condition of heat transfer from the outside being avoided and reduced pressure, the hydrocarbon composing the hydrate is gasified and, on the other hand,

the water molecules around the hydrocarbon become ice crystals.

[Page 408, upper right-hand column]

Therefore, in a liquified gas cold heat utilizing seawater desalination whereby a liquified gas and seawater are brought into direct contact under an elevated pressure, hydrate should be decomposed dissociation

dissoeiated and converted into ice crystals when the ~~decomposition~~ performance of the hydrate and the difficulty anticipated from performing a dissociation operation under an elevated pressure are taken into consideration.

The present invention was made while paying attention to the above-described point, and is aimed at providing a multi-stage hydrate decomposition tank, by improving the structure of the hydrate decomposition tank, which is capable of making the flow inside the decomposition tank active and the slurry flow through the orifice between stages easy.

The present invention being roughly described, the multi-stage hydrate decomposition tank according to the present invention is characterized by a deflector being provided on the downstream side of the orifice of the orifice plate between stages in a multi-stage hydrate decomposition tank provided in a frozen type seawater desalination apparatus.

Since the specific weight of the hydrate is nearly the same value as that of ice, the hydrate floats up from inside the brine inside the tank, etc., with little flow such that it makes difficult the flow in the orifice between stages of the hydrate decomposition tank.

[Page 408, lower left-hand column]

As to the present invention, a deflector is provided on the downstream side of the orifice of the orifice plate between stages in order to make active the flow of the slurry in the multi-stage decomposition tank and to make the flow the slurry through the orifice between stages, whereby a turbulent flow is provided to the liquid phase portion in the multi-stage decomposition tank, and the hydrate is efficiently decomposed and can be converted into ice crystals.

According to the experiments by the present inventors, etc., the particles of the ice crystals formed by the reduced-pressure decomposition of the hydrate increase in size when the decomposition time becomes long. Namely, Fig. 2, an attached drawing, is a graph illustrating the changes over time of the particle diameters of the ice crystals formed by the reduced-pressure decomposition of the hydrate, the horizontal axis illustrating hydrate decomposition time (minutes) and the vertical axis the particle diameter ( $\Phi m$ ) of the ice crystals formed by hydrate decomposition. As such, since the increase of the particle diameter of ice crystals is linked to the enhancement of dissociation performance, the longer the decomposition time is, the better it is as much as possible. To that end, it is desirable to lengthen hydrate decomposition time by making the decomposition tank multi-staged.

There are provided orifice plates between stages, as specifically shown in the drawing below, provided with an orifice acting as the slurry flow opening of  $d$  in  $\phi$  such that each stage diameter

has a pressure differential.

[Page 408, lower right-hand column]

Each of the decomposition chambers divided by these orifice plates consists of the liquid phase portion and the vapor phase portion, and in the gas phase portion there is present the decomposed

gas of the hydrate and in the liquid phase portion there are present the hydrate or ice crystals as they are mixed with brine to form a slurry. Since the specific weight of ice crystals and hydrate is about 10% less as compared to the specific weight of brine, the ice crystals or hydrate floats up to the upper portion of the liquid phase portion when there is little flow in the liquid phase portion, making difficult the passage thereof through the orifice provided at the lower portion of the liquid phase portion, making the decomposition operation impossible as the hydrate or ice crystals rise eventually to the vapor phase portion.

Accordingly, it is necessary to provide fluidity (turbulent flow) to the liquid phase portion so as for the ice crystals and hydrate to be dispersed nearly uniformly through the entire liquid phase portion.

In the present invention, there is provided a deflector at the rear side on the downstream side of the orifice to provide fluidity to this liquid phase portion. While there is no particular limitation placed on the dimension, location, and direction, etc., of this deflector,

[Page 409, upper left-hand column]

as to the angle of deflector  $\theta$ , the length of deflector  $P$ , and the width  $b$  it is appropriately set such that they are  $\theta = 70-80^\circ$ , the relation between  $P$  and  $b$  being  $P/d = 20-25$ , and  $b/d = 5-10$  respectively, and it was verified through an experiment that this allows the hydrate and ice crystals in the liquid phase portion to be uniformly dispersed.

Next, the present invention will be described in specifics with the use of attached drawings. Fig. 3 is a system diagram illustrating one example of the frozen type seawater desalination apparatus using a multi-stage hydrate decomposition tank according to the present invention, and Fig. 4 an enlarged view of the multi-stage hydrate decomposition tank in Fig. 3, 1 illustrating a crystallization tank, 2 a liquified gas vaporizer, 3 a liquified gas conduit, 4 hydrate, 5 vaporized gas conduit, 6 a pressure release valve, 7 a seawater conduit, 8 the liquid surface of seawater, 9 a hydrate and brine conduit, 10 the multi-stage hydrate decomposition tank, 11 an ice crystal and brine conduit, 12 a pump, 13 a dissociation tank, 14 a decomposed gas conduit, 15 a decomposed gas pressure release valve, 16 ice crystals, 17 brine, 18 a dissociation portion, 19 a brine conduit, 20, an orifice, 21 an orifice plate between stages, 22 the liquid phase portion, 23 the vapor phase portion, 24 a deflector,  $d$  the orifice diameter,  $\theta$  deflector angle,  $P$  deflector length.

[Page 409, upper right-hand column]

As shown in Fig. 3, in the crystallization tank 1 the liquified gas compression-fed [Page 407, upper half of the page]

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[Page 407, lower half of the page]

[Page 407, column (1)]

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2. A multi-stage hydrate decomposition tank as set forth in claim 1, with the angle of the deflector with respect to the orifice plate between stages being set to 70-80 degrees, the ratio of the length of the deflector with respect to the diameter of the orifice plate between stages being 20-25, and the ratio of the width of the deflector with respect to the diameter of the orifice plate between stages being 5-10.

#### Detailed Description of the Invention:

The present invention relates to a multi-stage hydrate decomposition tank, specifically, to an efficient multi-stage hydrate decomposition tank provided in a frozen type seawater desalination apparatus utilizing cold heat generated when a liquified gas such as LNG is gasified.

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and a type of clathrate compound wherein water molecules are bonded around a hydrocarbon molecule such as methane, ethane, and propane. For example, when a liquified gas and seawater are brought into direct contact under an elevated pressure of  $30 \text{ kg/cm}^2$ , a hydrate is formed at the seawater temperature of about  $8^\circ\text{C}$ . Therefore, the cold heat in conjunction with the evaporation of liquified gas is consumed for the formation of hydrate and the temperature does not drop to about  $-2^\circ\text{C}$ , the temperature at which ice crystals are formed in seawater, and only the hydrate is formed. While this hydrate is nearly the same in appearance as ice crystals, the particle diameter thereof is  $1/3$ - $1/4$  in particle size as compared to the particle diameter of the ice crystal formed when a liquified gas and seawater are brought into direct contact under a low pressure.

In the seawater desalination method by frozen method, naturally crystallization technology but the dissociation of ice crystals or hydrate formed in the crystallization tank and concentrated seawater (hereinafter referred to in short as brine) is also one of the important technologies. Now, the dissociation performance of ice crystals or hydrate and brine is subject to the sizes of the particles thereof, and the larger the particle diameter is, the more enhanced the dissociation performance is.

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And, the hydrate has a characteristic such that it decomposes by the pressure being reduced from the pressure at the time of crystallization to the ambient pressure, and about 93 kcal per 1 kg of hydrate is required for the decomposition heat then. Therefore, by the hydrate being decomposed in a container under the condition of heat transfer from the outside being avoided and reduced pressure, the hydrocarbon composing the hydrate is gasified and, on the other hand, the water molecules around the hydrocarbon become ice crystals.

[Page 408, upper right-hand column]

Therefore, in a liquified gas cryogenic heat utilizing seawater desalination whereby a liquified gas and seawater are brought into direct contact under an elevated pressure, hydrate should be decomposed

dissociation  
dissociated and converted into ice crystals when the decomposition performance and the difficulty anticipated from performing a dissociation operation under an elevated pressure are taken into consideration.

The present invention was made while paying attention to the above-described point, and is aimed at providing a multi-stage decomposition tank, by improving the structure of the

decomposition tank of hydrate, which is capable of making the flow inside the decomposition tank active and the slurry flow through the orifice between stages easy.

The present invention being roughly described, the multi-stage decomposition tank for hydrate according to the present invention is characterized by a deflector being provided on the downstream side of the orifice of the orifice plate between stages.

Since the specific weight of the hydrate is nearly the same value as that of the ice, the hydrate floats up from inside the brine inside the tank, etc., with little flow such that it makes difficult the flow in the orifice between stages of the hydrate decomposition tank.

[Page 408, lower left-hand column]

As to the present invention, a deflector is provided on the downstream side of the orifice of the orifice plate between stages in order to make active the flow of the slurry in the multi-stage decomposition tank and to make the flow the slurry through the orifice between stages, whereby a turbulent flow is provided to the liquid phase portion in the multi-stage decomposition tank, and the hydrate is efficiently decomposed and can be converted into ice crystals.

According to the experiments by the present inventors, etc., the particles of the ice crystals formed by the reduced-pressure decomposition of the hydrate increase when the decomposition time becomes long. Namely, Fig. 2, an attached drawing, is a graph illustrating the changes over time of the particle diameters of the ice crystals formed by the reduced-pressure decomposition of the hydrate, the horizontal axis illustrating hydrate decomposition time (minutes) and the vertical axis the particle diameter ( $\Phi m$ ) of the ice crystals formed by hydrate decomposition. As such, since the increase of the particle diameter of ice crystals is linked to the enhancement of dissociation performance, the longer the decomposition time is, the better it is as much as possible. To that end, it is desirable to lengthen hydrate decomposition time by making the decomposition tank multi-staged.

There are provided orifice plates between stages, as specifically shown in the drawing below, provided with an orifice acting as the slurry flow opening of  $d$  in  $\phi$  such that each stage diameter

has a pressure differential.

[Page 408, lower right-hand column]

Each of the decomposition chambers divided by these orifice plates consists of the liquid phase portion and the vapor phase portion, and in the gas phase portion there is present a decomposition gas of the hydrate and in the liquid phase portion there are present the hydrate or ice crystals as they are mixed with brine to form a slurry. Since the specific weight of ice crystals and hydrate is about 10% less as compared to the specific weight of brine, the ice crystals or hydrate flow up to the upper portion of the liquid phase portion when there is little flow in the liquid phase portion, making difficult the passage thereof through the orifice provided at the lower portion of the liquid phase portion, making the decomposition operation impossible as the hydrate or ice crystals rise eventually to the vapor phase portion.

Accordingly, it is necessary to provide fluidity (turbulent flow) to the liquid phase portion so as for the ice crystals and hydrate to be dispersed nearly uniformly through the entire liquid phase portion.

In the present invention, there is provided a deflector at the rear side on the downstream side of the orifice to provide fluidity to this liquid phase portion. While there is no particular

limitation placed on the dimension, location, and direction, etc., of this deflector,

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as to the angle of deflector  $\theta$ , the length of deflector  $P$ , and the width  $b$  it is appropriately set such that they are  $\theta = 70-80^\circ$ , the relation between  $P$  and  $b$  being  $P/d = 20-25$ , and  $b/d = 5-10$  respectively, and it was verified through an experiment that this allows the hydrate and ice crystals in the liquid phase portion to be uniformly dispersed.

Next, the present invention will be specifically described with the use of attached drawings. Fig. 3 is a system diagram illustrating one example of the frozen type seawater desalination apparatus using a hydrate multi-stage decomposition tank according to the present invention, and Fig. 4 an enlarged view of the hydrate multi-stage decomposition tank in Fig. 3, 1 illustrating a crystallization tank, 2 a liquified gas vaporizer, 3 a liquified gas pipe path, 4 hydrate, 5 vaporized gas pipe path, 6 a pressure release valve, 7 a seawater pipe path, 8 the liquid surface of seawater, 9 a hydrate and brine pipe path, 10 the multi-stage decomposition tank for hydrate, 11 ice crystal and brine pipe path, 12 a pump, 13 the dissociation tank, 14 a decomposed gas pipe path, 15 a decomposed gas pressure release valve, 16 ice crystals, 17 brine, 18 a dissociation portion, 19 a brine pipe path, 20, an orifice, 21 an orifice place between stages, 22 the liquid phase portion, 23 the vapor phase portion, 24 a deflector,  $d$  the orifice diameter,  $\theta$  deflector angle,  $P$  deflector length.

[Page 409, upper right-hand column]

As shown in Fig. 3, in crystallization tank 1 the liquified gas compression-fed from the liquified gas pipe path 3 is brought into direct contact with the seawater fed from seawater conduit 7 by the liquified gas vaporizer 2 such that hydrate 4 is formed in the crystallization tank 1, and the vaporized liquified gas flows out to the outside through the vaporized gas conduit 5 and the pressure release valve 6. The hydrate and brine formed in the crystallization tank 1 become a slurry and enters into the multi-stage hydrate decomposition tank 10 through the hydrate and brine conduit 9. The hydrate is converted into ice crystals from hydrate in said decomposition tank 10, and enters into the dissociation tank 13 through the ice crystal and brine conduit 11 and the pump 12. On the other hand, the decomposition gas generated in conjunction with the decomposition of the hydrate in said decomposition tank 10 flows out to the outside through the decomposed gas conduit 14 and the decomposed gas pressure release valve 15, and used mainly as a fuel. In the dissociation tank 13 the ice crystals 16 and the brine 17 are dissociated by the dissociation portion 18 provided in the dissociation tank 13, and the brine is discharged through the brine conduit 19.

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As shown in Fig. 4, in said decomposition tank 10 there are provided orifice plates between stages 21 provided with orifices 20 to provide a pressure differential at each stage, and each of the decomposition chambers divided by these is composed of the vapor phase portion 23 composed of the decomposed gas of hydrate and the liquid phase portion 22 composed of the mixed slurry of hydrate or ice crystals and brine. As previously described, there is provided a deflector on the downstream side of the orifice 20 in order to make decomposition operation smooth and to uniformly disperse ice crystals and hydrate in the entire liquid phase portion 22 by providing fluidity to the liquid phase portion 22, and a good decomposition effect can be

exhibited with the use of the location, angle, and dimension of the deflector under the above-described conditions.

As so far described, the present invention can provide a multi-stage decomposition tank for frozen type seawater desalination capable of effectively decomposing hydrate with the provision of an orifice having a suitable location, dimension, and angle on the downstream side of an orifice between stages.

Brief description of the Drawings:

Fig. 1 is a graph illustrating the dissociation performance of the ice crystals and hydrate from within the brine,

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Fig. 2 a graph illustrating the change over time in the particle diameter of the ice crystal formed by the reduced-pressure decomposition of hydrate, Fig. 3 a system diagram illustrating one example of the frozen type seawater desalination apparatus using the hydrate multi-stage decomposition tank according to the present invention, and Fig. 4 an enlarged view of the hydrate multi-stage decomposition tank in Fig. 3.

- 1.....Crystallization tank,      2.....Liquified gas vaporizer,      3.....Liquified gas conduit,  
4.....Hydrate,    5.....Vaporized gas conduit,    6.....Pressure release valve,    7.....Seawater  
conduit.      8.....Liquid surface of seawater,      9.....Hydrate and brine conduit,  
10.....Multi-stage hydrate decomposition tank,      11.....Ice crystals and brine conduit,  
12.....Pump,      13.....Dissociation tank,      14.....Decomposed gas conduit,  
15.....Decomposed gas pressure release valve,      16.....Ice crystals,      17.....Brine,  
18.....Dissociation portion,    19.....Brine conduit,    20.....Orifice,    21.....Orifice plate  
between stages,      22.....Liquid phase portion,    23.....Vapor phase portion,  
24.....Deflector,       $\phi$ .....Orifice diameter,  $\theta$ .....Deflector angle,  $P$ .....Deflector length.  
 $\alpha$

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Fig. 1

Fig. 3

[Graph]

[Drawing]

[Label for the Y axis]

Desalination rate

[Label for the X axis]

Height of the lamination layers of ice  
crystals and hydrate

Fig. 2

Fig. 4

[Graph]

[Drawing]

[Label for the Y axis]

Particle diameter of ice crystals formed  
by hydrate decomposition

[Label for the X axis]

Hydrate decomposition time (minutes)